EXECUTIVE SUMMARY

INTRODUCTION

The Picher Mining Field of northeastern Oklahoma was the location of extensive lead and zinc mining from 1904 to 1970. Mine waste accumulations and acid mine water discharge from the now-abandoned lead-zinc mines have become an environmental issue that has been the focus of environmental restoration activities since 1979. The area was designated by the Environmental Protection Agency (EPA) as the Tar Creek Superfund Site in 1983. Extensive underground openings left from the historic mining activity have also resulted in subsidence that presents a serious hazard to public safety, the environment, and current and future land use. The subsidence problem was not systematically addressed as part of the environmental restoration activities. In 2000, Oklahoma Governor Frank Keating established the Tar Creek Task Force to develop a holistic plan for addressing issues identified at the site. Mine subsidence was identified by the Tar Creek Task Force as a major concern, however, no funding was provided to implement recommendations made by the Tar Creek Task Force. In June 2004, Oklahoma Senator Jim Inhofe requested that an evaluation be conducted to assess the potential for future major subsidence in the area. The U.S. Army Corps of Engineers was designated to be the lead agency on the subsidence evaluation project. A technical team was assembled in August 2004 to begin the subsidence evaluation. Composition of the team is presented in Table ES.1, *Subsidence Evaluation Team Organization.*

TABLE ES.1
SUBSIDENCE EVALUATION TEAM ORGANIZATION

Organization	Team Member
Government Organizations	
U.S. Army Corps of Engineers, Tulsa District	Jonna Polk
	James Martell
U. S. Department of the Interior, U.S. Geological Survey	David Fittermen
	Mark Becker
	Bill Ellis
U.S. Department of the Interior, Office of Surface Mining	Len Meier
Oklahoma Conservation Commission	Mike Sharp
Oklahoma Department of Environmental Quality (DEQ)	David Cates
	MaryJane Calvey
Oklahoma Geological Survey	Ken Luza
U.S. Department of the Interior, Bureau of Indian Affairs	Charles Head
Quapaw Tribe	Tim Kent
Contractor Support	
Montgomery, Watson, Harza (MWH)	John Redmond
	Bruce Narloch
	Andrew Rossi
SubTerra, Inc.	Chris Breeds
Keheley & Associates, Inc.	Ed Keheley
Wood Metallurgical Consultants	Frank Wood
Others Contributing to the Evaluation Process	
Oklahoma DEQ	Kelly Dixon
U.S. Department of the Interior, Bureau of Indian Affairs	Bob Coleman
U.S. Army Corps of Engineers, Tulsa District	Adam Crisp
U.S. Department of the Interior, Office of Surface Mining	Paul Behum
MWH	John Pellicer
U.S. Department of the Interior, Bureau of Land Management	Doug Cook
Miami Integris Baptist Hospital	Dr. Mark Osborn

This report describes the evaluation process and the results obtained by the team and presents recommendations for mitigation or avoidance of the subsidence hazards.

The USGS served as an active member of the multi-agency Team by providing scientific and technical expertise to the subsidence evaluation process and by participating in the drafting of certain portions this report. However, consistent with agency policy, the USGS did not participate in the development of any recommendations contained within this report and USGS endorsement of any such recommendations should not be implied.

The subsidence study focused on residential areas and transportation corridors of major significance in the Picher Mining Field. Residential areas identified for evaluation in this study were the communities of Picher Cardin, Hockerville, and Quapaw. Mining records show that neither Commerce nor North Miami is significantly undermined. Mine maps for mines beneath the City of Quapaw were not located, and the only known information for the mines in the Quapaw area is the location of several mineshafts. Transportation corridors considered for evaluation in this study were Highway 69 from the junction of Highway 69 and 69A north through Picher to the Kansas state line, Highway 69A through Quapaw to the Kansas state line, East 20 Road (A Street) from the west side of Picher to the junction with Highway 69A, and Cardin Road from the junction with Highway 69 in Picher to the junction north of Commerce. These residential areas and transportation corridors are referred to collectively as the study area.

Public safety implications of subsidence have concerned the residents in the study area for many years. Shaft related and non-shaft related subsidence events have occurred in the Picher Mining Field since the beginning of mining operations and continue to occur. Unfortunately, records of the locations of past subsidence events are incomplete, and many events that occurred prior to 1960 were not recorded in a formal manner, which would allow for easy identification and analysis.

Several environmental issues are associated with subsidence in the study area: surface runoff into subsidence sites, modification to drainage systems, water quality degradation and the unauthorized dumping of commercial and residential trash in the subsidence sites. Surface water runoff problems have dated back to the beginning of mining in the Picher Mining Field. As the mines were abandoned and subsidence events occurred, surface runoff began to fill the mines and the larger subsidence features. A recent field evaluation of mine shafts and subsidence features identified an extensive amount of commercial and residential waste in open mine shafts, and shaft related and non-shaft related subsidence features. Examples of waste found include animal carcasses, chemicals, human waste, tires, construction materials, and motor oil.

Residents and city, state, federal, and elected officials have discussed the safe and economical use of the undermined lands in northeastern Ottawa County for many years. The vast extent of the underground mine workings, the potential for future subsidence, and the large amount of surface area covered by mill tailings have hampered the ability to reasonably explore viable future land use options for the study area.

To address the above concerns, the Subsidence Evaluation Team identified two primary products that would be necessary to estimate the location, extent and magnitude of future mine subsidence in the study area. These products are:

- Exhibits that depict the location of mine workings, shaft locations, non-shaft related collapses, roof falls, and the estimated maximum subsidence from mine workings combined into one map per section.
- Figures that present the results of the analytical tool used to determine the probability of subsidence based on pre-1973 major subsidence at or adjacent to major transportation corridors, residences and structures. This is recommended as a tool to prioritize areas for further evaluation and mitigation.

Estimated Maximum Subsidence

Site-wide information on geology, mine map availability, and drill-hole logs were reviewed. The Evaluation Team had mine maps from multiple sources and drill-hole logs from Missouri Southern State

University scanned. High-resolution aerial photography and other supporting data were obtained from numerous sources.

Exhibits were prepared to show the estimated maximum subsidence from the mine workings in the study area. Estimated maximum subsidence was defined for this study as the maximum amount of subsidence (measured in feet) that could occur at a given surface location as a result of the collapse of mine workings. This value is calculated based on the height of the mine workings and bulking factors for the geologic units over the mine workings. In other words, if the material over mine workings were to collapse, the maximum amount of subsidence that could propagate to the surface is equal to the height from the floor of the mine working to the surface minus the height of the overlying material, multiplied by a bulking factor. The maximum estimated subsidence values were grouped into six categories and ranged from less than 2 feet to greater than 50 feet.

A total of 286 numbered locations in the study area were predicted to have some degree of subsidence if the mine workings were to collapse. A 150-ft buffer zone was drawn around the sites to account for mine-map-location inaccuracies and an angle of draw. The summary of subsidence locations (numbered sites) within the study area includes:

- 54 locations under or within approximately 150 feet of residences or structures
- 33 locations under or within approximately 150 feet of major transportation corridors
- 13 locations under or within approximately 150 feet of both residences or structures and major transportation corridors
- 3 locations under or within approximately 150 feet of public use areas (parks, playgrounds)
- 183 locations under or within approximately 150 feet of other areas or structures not listed above (city streets, rural roads, pasture lands, chat piles, wooded lands, wetlands, and other undeveloped land)

Undermined rural locations outside of Picher, Cardin, and Hockerville with potential subsidence are divided into the following categories:

- 7 locations under or within 150 feet of Residences or Structures
- 29 locations under or within 150 feet of major transportation corridors
- 17 locations under or within 150 feet of rural roads
- 0 locations under or within 150 feet of public parks and playgrounds
- 3 locations under or within 150 feet of railroads

The summary of the residential structures, parks and playgrounds, community streets and major transportation corridors that are above and/or within 150 feet of the locations of estimated maximum subsidence in the three communities in the study area includes:

Picher

- 139 Residential Structures
- 11 Business Structures
- 13 Public Use Structures/Facilities:
  - 6 Churches
  - 1 City Maintenance Facility
  - 1 Lodge Facility
  - 1 Picher Mining Field Museum
  - 4 Parks/Playgrounds
- 53 streets are above and/or within 150 feet of a potential subsidence location

- 25 locations under and/or within 150 feet of a major transportation corridor within the city limits

A total of 159 residential, business and public use structures in Picher have the potential of some degree of subsidence. This number does not include the 4 public use parks/playgrounds. Eleven of the residences and one business appear to be abandoned.

Cardin

- 33 Residential Structures
- 6 Business Structures
- 3 Public Use Structures/Facilities
  - 3 Churches
  - 0 Public Parks and Playgrounds
- 14 streets under and/or within 150 feet of a potential subsidence location
- 4 locations under and/or within 150 feet of a major transportation corridor

A total of 42 residential, business and public use structures have the potential of some degree of subsidence. Three residences and four businesses appear to be abandoned.

Hockerville

Undermined areas within Hockerville are defined for purposes of this report as the area between 20 Road to the south and State Line Road to the north, and 604 Road to the west and 610 Road to the east.

- 4 Residential Structures
- 1 Business Structure
- 1 Public Use Structure/Facility:
  - 1 Church
  - 0 Public Parks and Playgrounds
- 7 locations under and/or within 150 feet of Community Streets
- 1 location under and/or within 150 feet of a Major Transportation Corridor

Probability Analysis

Mechanisms leading to subsidence, based on previous experience in analyzing and predicting subsidence potential, were reviewed to determine if subsidence prediction methods were available for application in the study area. Due to the unique mining methods used in the Picher Mining Field, none of the subsidence prediction methods reviewed was directly applicable to the study, but rather served as relevant background for development of the subsidence evaluation.

Information available for the Picher Mining Field related to mine subsidence is generally limited to mine mapping and geologic information. The lack of detailed rock mechanics data for the study area and the need to use available information in any forward analysis limited the analytical approach for this subsidence evaluation. Therefore, several large non-shaft subsidence areas and non-subsidence areas were back-analyzed to identify factors that control non-shaft related subsidence in the study area.

The purpose of the back-analysis of large, existing subsidence features resulting from mine collapse was to identify those factors or combinations of factors that are common to those features. Variables associated with past surface collapse and non-collapse case studies were tabulated and analyzed statistically to

determine the factors and/or combinations of factors that appeared to be most associated with large surface collapses. These critical factors were then used to evaluate the probability of future subsidence in the target areas based on a representative sampling of major subsidence documented to have occurred prior to 1973. Target areas where such factors are present, and are considered to have a higher probability, can be prioritized for future assessment and mitigation.

One of the major limitations to this approach is that all but one of the subsidence cases selected for back-analysis were major surface collapses, with horizontal dimensions on the order of 100 feet or greater and subsidence of several tens of feet. These larger features were selected because they represent the greatest potential threat to public safety and almost certainly result from the collapse of large underground rooms, or stopes. Smaller subsidence features, which do occur in the Picher Mining Field, are less easily identified and can result from processes other than mine collapse, such as shaft cribbing failure and dissolution of limestone resulting in karstic features. Trough subsidence, characterized by shallow subsidence over relatively large areas, was also not included in this analysis. Trough subsidence, while possibly present in the Picher Mining Field, is not easily identified and has not been well defined in the region. The screening criteria that result from this back-analysis are therefore only applicable in identifying potential areas of large surface collapse similar in nature to the back-analysis case studies considered.

The probability of subsidence, based on a representative sampling of major subsidence that occurred prior to 1973, was evaluated for 133 areas where subsidence could occur within 150 feet of residences, other structures or major transportation corridors. The evaluation provides a numerical prediction of the probability of future subsidence at these locations based on the similarity in characteristics with those of the collapsed mine workings of the back-analysis case studies. This method cannot predict when subsidence will occur. The probability analysis is useful as a tool to prioritize locations to be addressed.

From the data assembled and evaluations completed as part of this study, the following is a summary of the major findings:

- 3,130 acres in the 4,400-acre study area were not undermined. However, 1,270 acres were undermined, of which 88 acres displayed greater than nominal potential for subsidence. The 88 acres found to display greater than nominal potential for subsidence were identified as 286 separate locations and/or clusters.
- Subsidence can occur with little or no advance warning.
- Methodologies are not currently available to accurately predict when subsidence will occur.
- 473 acres of the 1,390 acres of the town of Picher that are located within the study area are undermined.
- 17 acres of the 58 acres of the town of Cardin that are located within the study area are undermined.
- 25 acres of the 231 acres of the town of Hockerville that are located within the study area are undermined.
- The Subsidence Evaluation Team located no maps of mines in the vicinity of the town of Quapaw, and as a result, the extent of the undermining of Quapaw is unknown. The presence of mine shafts and mill sites in the area, however, indicates that significant mining may have occurred beneath the town.
- 4.5 miles of the 19 miles of major transportation corridors in the study area are undermined.
- 15 shaft related and 20 non-shaft related subsidences have occurred in the study area since the 1982 inventory by OGS.

- Factors identified as contributing most to non-shaft related subsidence are width of stope, height of stope, combined thickness of the Boone Formation and Chester above the stope, and depth of stope.
- Current groundwater levels in the study area provide a buoyant effect that reduces the effective load on remnant pillars and mine roofs and therefore may decrease the potential for subsidence.
- Mine maps are of different vintages and the most recent maps do not always include mine workings shown on older maps. Also, discrepancies exist between mine maps within the same lease.
- Map symbols used to indicate different mine levels can be inconsistent from lease to lease, and in some cases are inconsistent within the same lease.
- Interpretation of mine maps is sometimes difficult in areas of multiple-level mining because of overlapping and/or inconsistent map symbols.
- The mine floor and roof elevations can be estimated by using assay data from exploration borehole logs.
- The geology is variable within short distances, as indicated by the exploration borehole logs and available published reports.
- The extraction ratio for many of the mines, calculated from the detailed mine maps, is greater than 90%.
- There is very little existing geotechnical or rock mechanical data to assess the probability of subsidence using available analytical methods.
- There is very little documentation available regarding the shaving and removal of pillars, except for a few isolated cases.
- Details of the mechanics of non-shaft related subsidence in the study area are poorly understood.
- Post-mining subsidence features (post-1970) in the Picher Mining Field have tended to be smaller in size than previous collapses, perhaps indicating a differing collapse and subsidence mechanism than in the earlier collapses.
- Some existing houses in the Picher area most likely do not meet HUD requirements for habitability or for financing home improvements or sales.
- Some areas in the mining field are not suitable for residential or business development given the safety risks and the cost to mitigate them.

Conclusions

The major conclusions of this study include:

- The potential for shaft related and non-shaft related subsidence is a very serious threat to the safety and economic well-being of people who reside in and travel through the area.
- The area exposed to subsidence hazards is a relatively small percentage of the total study area, but some residential and public-use areas and portions of transportation corridors are subject to some degree of subsidence hazard.
- 4,312 acres (not including buffer zones) of the 4,400-acre study area are not subject to subsidence based on limited evaluation of available information from mine maps and conservative estimates of rock bulking factors. Further review of all available information may reveal additional areas subject to potential subsidence.

- Based on the back-analysis of failed mine workings, it is probable that additional non-shaft related failures will occur in the future.
- Every shaft has the potential to collapse, and the initial opening of a shaft collapse is likely to be the dimension of the shaft, and may grow as large as 30 feet in diameter.
- The quantifiable variables of 1) width of stope, 2) height of stope, 3) combined thickness of Boone Formation and Chester above the stope, and 4) depth of stope can be effectively used to estimate the probability of subsidence.
- A preliminary predictive tool has been developed that enables prediction of the probability of future subsidence potential in the Picher Mining Field.
- The magnitudes of possible subsidence at locations evaluated in this study range from less than 1 foot to greater than 50 feet, with the attendant possibility of loss of life and/or property, depending upon where the subsidence occurs.
- Land use determines the potential impact of a subsidence event on the population. For example, a one-foot subsidence in a road has more serious consequences than a similar or even larger subsidence in an agricultural area.
- Lowering of the groundwater table to levels below mine roof elevations may locally increase the probability of subsidence. This would probably only occur through pumping. However, water level fluctuations may cause increased shaft related collapses.
- A thorough evaluation of subsidence potential of a mined area must include a careful review of all available mine maps.
- It is likely that subsidence features exist in the study area and were not identified.
- No funding mechanism exists for emergency response to subsidence.

General Recommendations

Based on the results, findings and conclusions of the study, recommendations were developed for the study area. The recommendations are divided into two major categories. The first contains a list of general recommendations that constitute the minimum safety approaches that should be implemented. The second contains a list of site specific recommendations that require a more comprehensive management evaluation to implement. Due to the anticipated high cost of some of the recommendations, the Subsidence Evaluation Team recommends using a cost-benefit analysis as the primary management tool for decision making. A cost-benefit analysis of all available options should be performed to provide the basis for determining the most appropriate final decision.

The following constitute a summary listing of the Subsidence Evaluation Team's general recommendations:

- Establish an advisory committee composed of federal, state, and local representatives to assist with the implementation of recommendations contained in this report and to serve as a technical and/or management resource for policy makers and elected officials.
- Establish a long-term program to locate, map, and record future subsidence events as they occur in the Picher Mining Field. Both shaft related and non-shaft related subsidence events should be included in the program.
- Establish a fund to address emergency subsidence events in the Picher Mining Field. The fund should provide for emergency evaluation of subsidence features as they occur and provide an immediate funding source for corrective measures. Existing funding mechanisms do not provide the ability to respond quickly to emergencies. The fund would be replenished as it is drawn down.
- Continue the current mine-shaft closure program to remove the immediate hazards associated with open shafts, further reduce the potential for additional shaft failures, and minimize the

environmental impacts from surface water drainage and unauthorized dumping. Focus mine-shaft closure efforts first on open mine shafts within city limits and near occupied structures.

- Develop and implement a subsidence training program for workers from Picher, Quapaw, Commerce, Ottawa County District 1, and Oklahoma Department of Transportation (ODOT) maintenance staff. The program should be designed to teach workers to recognize and report subsidence events and how to take appropriate action to address the subsidence events as they occur. A similar program was developed in Joplin, MO, and has worked effectively for several years.
- Identify and inspect all shaft related and non-shaft related subsidence features being used as dump sites for commercial and household refuse to reduce the environmental impacts of open subsidence features. A priority ranking based on the potential environmental impact should be developed and additional funding provided to eliminate surface runoff into the sites and, in some instances, close the sites not currently addressed. Governmental regulatory agencies, cities, and Ottawa County should work together to strengthen the regulations, enforcement, and penalties for unauthorized dumping and develop legal alternatives for trash disposal.
- Federal and State agencies involved in remediation and reclamation of lands at Tar Creek should reevaluate existing assumptions and approaches used to address hazards in the mining field. The information contained in this report (potential subsidence and mine shaft failure, underground mine workings) should be factored into existing projects, plans, and decisions. A process for evaluating current and future land use plans against existing hazards and the estimated cost for remediation and reclamation should be developed. A plan for restoration and/or final disposition of mined properties, including identification and mitigation of known hazards, should be a product of the effort. Ottawa County and impacted cities should establish a county-city land use planning process to evaluate current land use and develop future land use recommendations in the study area. Ottawa County should adopt building standards and land use guidelines for the mined lands.
- HUD regulations related to existing housing and future construction in the mining field should be reviewed to determine the applicability and impact.
- Identify a state agency responsible for maintaining and building upon the GIS developed from this project. The GIS information should be made available over the Internet or by some other electronic media.
- Complete subsidence evaluation for the remainder of the Picher Mining Field outside the study area and:
    - Further refine the subsidence evaluation model
    - Evaluate the effects of mine water on the stability of mine workings
    - Develop a better understanding of structural geology and physical and engineering properties of rock in the area
    - Incorporate additional mine maps and borehole data in the GIS
    - Evaluate failure mechanisms for recent smaller, non-shaft subsidence areas

SITE-SPECIFIC RECOMMENDATIONS

Given the study's conclusions, measures are required to mitigate the potential adverse impacts to public safety. Prior to implementing the following recommendations, a cost-benefit analysis should be performed to determine the most appropriate approach. Areas with higher probabilities of subsidence and greater consequence should be given priority with regard to evaluation and mitigation. The following constitute a summary listing of the Subsidence Evaluation Team's site-specific recommendations for public use areas, residential/commercial areas, major transportation corridors, residential streets and rural, agricultural and undeveloped areas:

For Public Use Facilities—Areas Where People Congregate Having a Maximum Estimated Subsidence of Five Feet or Greater:

- Three options are available: close/relocate the facility, conduct a site-specific evaluation followed by either a geotechnical evaluation, or perform regular monitoring using visual or geotechnical methods. The costs of the evaluation, and possible long-term monitoring should be determined. The benefits of continuing to use these facilities should be evaluated against the risk and overall costs of closure/relocation, the geotechnical evaluation, and long term-monitoring.
- Locations in Picher where residents were previously evicted by the Eagle-Picher Mining & Smelting Company and public use was restricted by Eagle-Picher and BIA because of the potential for subsidence should be further evaluated prior to development of public use facilities or expansion of residential areas. The grade school playground (location 139), the youth soccer field (location 141), Reunion Park (location 140), Picher Little League Park (old baseball field in Picher on South Main between 5th and 6th Streets), between 1st and A Streets and north of D Street between Netta and Picher Streets, and other areas of high public use should be evaluated to determine if continued use is safe for residents.

Residential/Commercial Areas:

- Mineshafts in Residential, Commercial or Public Use Areas: City and county workers should be trained to recognize the signs of potential mineshaft failure and periodically inspect all mineshafts located in the community. These areas should be zoned to restrict future residential, commercial, or public land use. The mine shafts should be investigated to determine if they are filled with durable material. If it is not, the shaft should be backfilled or plugged with concrete at the rock interface.
- Mineshafts Beneath Structures: If a structure is located immediately over a shaft, the structure should be relocated or demolished, or if cost effective, an angle drilling program should be conducted to determine if the shaft is completely backfilled. If drilling determines that the shaft is not completely backfilled or otherwise adequately plugged, the shaft should be backfilled or the structure should be relocated or demolished. After relocation or demolition of the structure, the shaft should be plugged at the rock interface or backfilled with non-degradable material. The cost of backfilling a shaft under a structure using angle drilling and grouting methods can be substantially greater than backfilling or plugging the same shaft without the structure. This entails drilling to determine the presence of mine voids and their depth and height, along with rock mechanics properties of the formation.
- Estimated Maximum Subsidence Five Feet or Greater: When a structure or structures overlies, or is within 150 feet of such an area, one of three options should be undertaken: perform exploratory drilling to determine the actual subsurface conditions, relocate the structure or structures, or demolish the structure or structures. Exploratory drilling may validate the original prediction, may show that the maximum estimated subsidence is either greater or less, and/or may reveal different information about the site such as the progression of mine roof collapse upward. If drilling shows that the site is not safe for continued occupation or use and mitigation is not a feasible option, then relocation or demolition should be conducted. Any demolition must be followed by restrictions on future land uses. It is recommended that no new construction or relocation of residential housing, commercial buildings, infrastructure, or transportation systems be allowed immediately above or within 150 feet of undermined lands until the area is evaluated for potential subsidence.
- Residential Areas of Quapaw: Based on the small number of mine shafts identified in Quapaw, the mine workings are most likely not extensive or located near the surface. Competent limestone is found near the surface in other mines near Quapaw indicating a competent mine roof structure. The cost to perform a geotechnical evaluation to identify

the extent of the mine workings, the height of the workings and the stability of the roof structure would be very expensive and disruptive to the community. Based on the absence of non-shaft related subsidence in the past, city workers should be trained to recognize and report any indications of subsidence or shaft failure.

Major Transportation Corridors:

Even small collapses on transportation corridors have the potential to cause serious accidents. For all transportation corridors that have an estimated maximum subsidence of 0 to 2 feet, under or within 150 feet of the road, establish and implement a routine survey grade monitoring procedure, the results of which are reviewed by a qualified engineer on a prescribed schedule.
For all transportation corridors that have an estimated maximum subsidence of 2 feet or greater, under or within 150 feet of the road, or where a mine shaft is located under the road right of way, immediate recommendations are:

- Inform transportation and utility managers of potential risk
- Consider imposing weight restrictions and speed limits on vehicles
- Establish alternate routes for school buses

Long-term recommendations are:

- Establish a systematic, continuous monitoring and reporting program including at a minimum, survey grade network along effected areas.
- Ensure that a qualified engineer or geologist reviews the monitoring data at regular intervals as a check on the quality control for the monitoring system.
- Conduct a geotechnical investigation to determine the stability of the road bed, surface and right-of-way.
- Train city, county and state transportation workers to recognize the signs of subsidence of shaft failure and provide a mechanism to expedite response to any suspected problem.
- Establish a standard protocol for all city, county and state officials to use whenever they suspect that a shaft failure or subsidence may be occurring in or adjacent to a road. This should include notification procedures, road closure procedures warning sign procedures, etc.
- Consider mitigation if cost effective

Residential Streets:

Several residential streets in Picher, Cardin, and Hockerville have the potential for subsidence beneath or adjacent to the streets. Several streets in these towns have been built over mine workings; however, not all streets built over mine workings were identified as having a potential for subsidence. Federal, state, and local officials should assess the need for evaluating the streets having a potential for subsidence and other streets that overlie mine workings. For all residential streets that have an estimated maximum subsidence of 0 to 2 feet, under or within 150 feet of the road, establish and implement a routine survey grade monitoring procedure, the results of which are reviewed by a qualified engineer on a prescribed schedule.

For residential streets that have an estimated maximum subsidence greater than 2 feet, immediate recommendations are:

- Consider imposing weight restrictions and speed limits on vehicles
- Establish alternate routes for school buses

Long-term recommendations are:

- Establish a systematic, continuous monitoring and reporting program including at a minimum, survey grade network along effected areas.
- Ensure that a qualified engineer or geologist reviews the monitoring data at regular intervals as a check on the quality control for the monitoring system.
- Conduct a geotechnical investigation to determine the stability of the road bed, surface and right-of-way.
- Train city, county and state transportation workers to recognize the signs of subsidence of shaft failure and provide a mechanism to expedite response to any suspected problem.
- Establish a standard protocol for all city, county and state officials to use whenever they suspect that a shaft failure or subsidence may be occurring in or adjacent to a road. This should include notification procedures, road closure procedures warning sign procedures, etc.
- Consider mitigation if cost effective

Rural, Agricultural and Undeveloped Areas

Areas used for pasture, hay, or row crops, and undeveloped areas used for hunting, off-road vehicle use, or hiking expose fewer people to dangers associated with subsidence than do roads or residential areas; yet, dangers to public safety and property still exist. Undeveloped and lightly developed portions of towns are likely locations for new construction or relocation of existing structures from other areas. It is recommended that no new construction or relocation of residential housing, commercial buildings, infrastructure, or transportation systems be allowed immediately above or within 150 feet of undermined lands until the area is evaluated for potential subsidence.

Options

In addition to the recommendations, the report also presents options to address some of the existing subsidence features. The options are divided into four categories including:

- Management approaches that may be used to address subsidence.
- Instrumentation that could be installed for early detection of potential surface collapse.
- Mine geometry characterization to better understand the parameters contributing to potential surface collapse.
- Hazard mitigation options (hazard abatement) associated with subsidence